Marine Policy 86 (2017) 214–233

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

U.S. Gulf of Mexico deepwater pipeline construction – A review of lessons learned

Mark J. Kaiser

Center for Energy Studies, Louisiana State University, Baton Rouge, LA 70803, United States

ARTICLE INFO

Keywords:
Activity indicators
Construction factors
Offshore development
Pipeline construction

ABSTRACT

The purpose of every offshore oil and gas pipeline is to transport fluid through a conduit from one point to another, but differences in field location, water depth, development strategy, time of sanction, seafloor topography, ownership and other factors means that installed mileage is expected to have complex site, time and location dependencies. The purpose of this review is to describe and illustrate the main factors that impact pipeline construction in the deepwater U.S. Gulf of Mexico. Understanding the nature of these dependencies and the manner in which factors interact and impact pipeline construction is the principal goal of this review. System attributes and their impact on activity drivers are described using a series of mini case studies. Lessons learned are synthesized and summarized.

1. Introduction

The U.S. Gulf of Mexico (GoM) has produced about 20 billion barrels (Bbbl) of oil and 186 trillion cubic feet (Tcf) of natural gas through the end of 2016 (Figs. 1 and 2). More than half of the crude oil (12.1 Bbbl oil) and about 80% of the Gulf's natural gas (159 Tcf gas) have been produced in water depths less than 400 ft, but since the mid-to-late 1980s both shallow water oil and gas production has been in steady decline.

In water depths greater than 400 ft and referred to as deepwater, oil production continues to increase, marked by fluctuations due to hurricane activity and the Macondo oil spill, as well as the intermittent nature of bringing a small number of capital intensive developments online. Deepwater oil production has outpaced the shallow water decline but natural gas production in the GoM continues to decrease because the deepwater region is oil-prone.

At the beginning of offshore exploration in the GoM, platforms were installed for exploration drilling and (if successful) production, but mobile offshore drilling units (MODUs) such as jackups quickly evolved to take their place since it was much more efficient and cost effective to employ a mobile platform for exploration and a fixed platform for development after a discovery was made.

Gas export lines were installed from structures with full processing capacity during the first decade of development because of the widespread distribution of gas fields in shallow water. As oil fields were found in increasing numbers oil export lines were installed. Today, the raw fluids from wells are separated into liquid and gas components to ensure efficient and reliable transportation, but this is not always necessary and in the early stages of the network build out many variations were pursued.[1] Export pipelines are usually single-phase (i.e., oil or gas), but multiphase (oil and gas, oil and water, gas and condensate, oil gas and water) pipelines were also employed under certain conditions (e.g., close to shore, low volumes, transition stage). All pipelines obey the same laws of physics and perform similar functions, but because liquids are essentially incompressible and gas is highly compressible, the operational aspects of liquid and gas pipelines and one-phase versus two-phase pipelines differ in significant ways.

Later developments employed simpler structures developing smaller reservoirs and tied-back to structures with processing capacity and export pipeline. For small reservoirs requiring only a few wells, a caisson or well protector would be placed around the wellbore for protection and to hold the tree and a few pieces of equipment such as meters and compressors (Fig. 3). Production of the raw fluids was routed using a flowline to a platform with processing capacity that exported the product to market/shore.

As discoveries were made in deeper water in the mid 1980s, the export oil and gas pipeline networks grew in size and connectivity. Although operators have no control over the location of fields, there are usually several options for the destination of export lines. Most new installations connect with existing pipeline systems to save cost and

E-mail address: mkaiser@lsu.edu.

[1] By transporting multiphase fluids in a single pipeline, separate pipelines and receiving facilities are eliminated, reducing capital expenditures. On the other hand, separating the phases with water disposal will reduce the size of the pipeline/handling facilities and maintenance requirements. The trade-off is between initial capital expenditures and long-term operating expenditures.

http://dx.doi.org/10.1016/j.marpol.2017.08.022
Received 1 July 2017; Received in revised form 22 August 2017; Accepted 23 August 2017

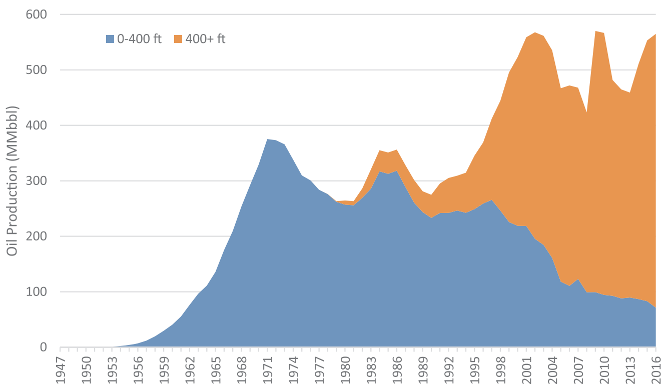

Fig. 1. Oil production in the Gulf of Mexico. Source: BOEM March 2017.

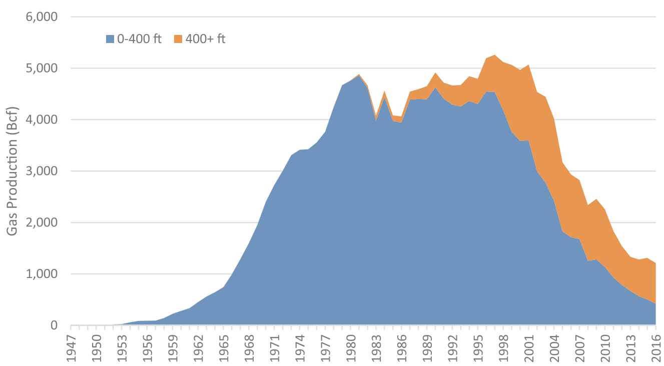

Fig. 2. Gas production in the Gulf of Mexico. Source: BOEM March 2017.

accelerate schedule. For some developments, however, new lines direct to shore facilities were installed to handle the large production volumes or for strategic reasons. In some cases, ownership or regulatory requirements prompted sharing pipeline infrastructure, while in other cases, competition excluded cooperation. Flowlines, umbilicals, and service lines became more prevalent with the use of 'wet' wells (also called subsea completions) where the wellhead and tree resides on the seafloor. Flowlines transporting raw multiphase fluids in shallow water were already in use at caissons and well protectors, but in deepwater, temperatures are colder, pressures are higher, and distances are longer which can cause difficulty in maintaining flow unless systems are carefully designed and operated.

All of the natural gas and almost all (98%) of the crude oil produced in the GoM is transported via pipeline, and among the world's offshore regions, the GoM has installed more pipeline than any other region (Fig. 4). The GoM pipeline network has evolved over many decades and crisscrosses much of the region, but about 40% of the installed pipeline has now been decommissioned. The total installed pipeline in the GoM circa 2017 was about 45,000 miles (72,500 km), enough to circle the earth at the equator almost twice, and total active mileage was 23,000 miles.

The U.S. Bureau of Ocean Energy Management (BOEM) is the federal agency responsible for leasing the U.S. Outer Continental Shelf (OCS) for oil and gas development. As with many development activities, offshore exploration and development requires environmental impact statements (EIS). The environmental impacts of leasing, development and production are evaluated as part of BOEM's compliance with the National Environmental Policy Act which requires federal agencies to study the environmental impacts of their decision-making [37]. One source of environmental impacts is pipeline construction due to the impacts of installation and potential spillage.

The purpose of this paper is to identify and discuss the main factors involved in deepwater pipeline construction activity. Only projects as-built are observed, however, and operator preferences are unknown except as realized vis-a-vis the resulting development. Hence, the focus of this review is on lessons learned *after* development concepts have been selected. For additional background information on GoM pipeline installation and decommissioning cost, see [18,19], and for application of EIS planning to offshore service vessels, see [17].

The paper is organized as follows. The components utilized in offshore production systems define the terms used throughout the review, and is followed by a high-level conceptual description of the basic issues involved in flow assurance and field development. The role of hub platforms, flowline architecture, reservoir quality, pipeline routing, ownership and pipeline reuse are described. Summary discussion and conclusions complete the survey.

2. Production system components

During production, oil and gas flow from the reservoir to the processing facilities and then onward to their sales destination through different channels and restriction points: beginning at reservoir pores, through well perforations and tubing, production chokes, valves, and pipelines on the ocean floor and up through the water column to topsides equipment for processing, before returning to the seafloor onward to market via pipeline or to a shuttle tanker.

Offshore oil and gas pipeline systems are distinguished according to their degree of processing. Export pipelines generally refer to lines associated with transporting processed oil and gas streams from a production platform to shore, also commonly referred to as sales quality oil and gas pipelines, while pipelines associated with delivering (unprocessed) raw fluids from subsea wellheads or another structure to a host facility for processing are referred to as infield flowlines (flowlines), gathering lines, or bulk lines.

Dry tree wells have their wellheads above the waterline and production fluids only need to transit the water column through a conductor or riser to reach the facility. Wet wells have their wellheads and trees located on the sea floor and need to be controlled via umbilicals and have flowlines on the seabed from the well to the host. Direct vertical access (DVA) wells are a special type of wet well where the wellhead and tree are located on the seafloor but direct access[2] is available from the structure.

Umbilical lines provide chemicals, control, and power to wet wells from the host platform. Strictly speaking, umbilicals are usually not considered 'pipeline' since their main purpose is to provide power and control to subsea wells via electro-hydraulic signals, but many umbilicals also contain tubes for chemical delivery so they also serve a fluid transport function. Umbilicals are used to deliver chemical inhibitors for hydrate, wax, asphaltenes, corrosion, and scale and are an integral part of flow assurance. Separate tubes within the umbilical are used for each chemical. For high volumes dedicated service lines for methanol, water, gas lift, etc. may be used instead of umbilical tubes.

Risers are the fluid transfer system linking the seabed and the deck and are associated with drilling, production and import/export pipelines. Risers are different than the pipelines and flowlines that reside on the seabed since they are subject to a range of changing forces over long periods of time. Ocean currents, water pressure, vessel motion, and wave actions are the primary forces that risers encounter over their lifetime, and therefore, must be designed to minimize fatigue damage. Risers attached to fixed platforms are also considerably different than risers attached to floating structures.

[2] DVA wells are employed to reduce platform weight and have the benefit of platform rig access, but unlike other wet wells, there is very little flowline or umbilical requirements.